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The Dunemann Option: Small Scale Production of Tree Seedlings

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ABSTRACT

The Dunemann method of seedling production uses forest tree litter as a growing medium instead of mineral soil. Trials to determine the value of this procedure as an alternative to conventional nursery or greenhouse production were conducted at the Midhurst Research Station with red pine, white pine, white and Norway spruce.

The white spruce and red pine duff that were used as growing media, were equally productive and remained fertile for at least four crops.

Production costs with the Dunemann system were lower than with conventional nursery seedlings because no fertilizers and herbicides had to be applied. Higher seedbed densities were used, resulting in more efficient use of growing space. Seed efficiency was higher, because fewer seeds were required to produce a shippable seedling.

Dunemann white pine and white and Norway spruce seedlings matched survival and growth of similarly aged conventional nursery stock but did not outperform in total height, older aged nursery stock. Dunemann red pine performance was inferior. Dunemann stock quality, especially red pine, probably could be improved by lowering seedbed densities.

The use of Dunemann beds for growing 1-year-old deep rooting species is briefly mentioned.

It is suggested that, in situations where seedling production targets are low, the Dunemann option could be considered as an alternative to field or greenhouse seedling production.

INTRODUCTION

The Dunemann System

The Dunemann system of seedling production uses a growing medium of needle litter or duff, which is put into raised wooden frames or in shallow excavations. This system was developed by Adolf Dunemann in Germany in 1939 (Aldhous, 1962). By 1950 the Dunemann system was widely used in West Germany at which time it was introduced to England by Grant (1952), who felt the Dunemann process was well suited for small scale operations and could be located on any type of ground.

The well drained, nutrient rich, organic rooting medium is the key to this technique (Aldhous, 1962). Litter is a major source of nutrients and has excellent aeration (Armson, 1977), making cultivation and fertilizer amendments largely unnecessary. Optimal conditions for seedling growth are maintained with partial shading and periodic irrigation (Aldhous, 1962). Weed control costs are reported to be less than at conventional nurseries due to reduced weed competition and herbicide requirements. Dunemann seedbeds are easy to construct and operate (Fig. 1).

The Dunemann Option for Ontario

Mullin and Leech (1959) reported on 2+0 red pine (Pinus resinosa Ait.), white pine (Pinus strobus L.) and white spruce (Picea glauca (Moench) Voss) Dunemann stock produced at Orono nursery (44°N, 79°48'W). The Dunemann stock survived poorly in comparison with 2+2 nursery stock but better than 2+1 nursery stock. Mullin (1968) concluded that Dunemann stock did not outperform 2+1 or 2+2 stock and suggested that 2+0 Dunemann stock was probably not hardy enough for field planting.

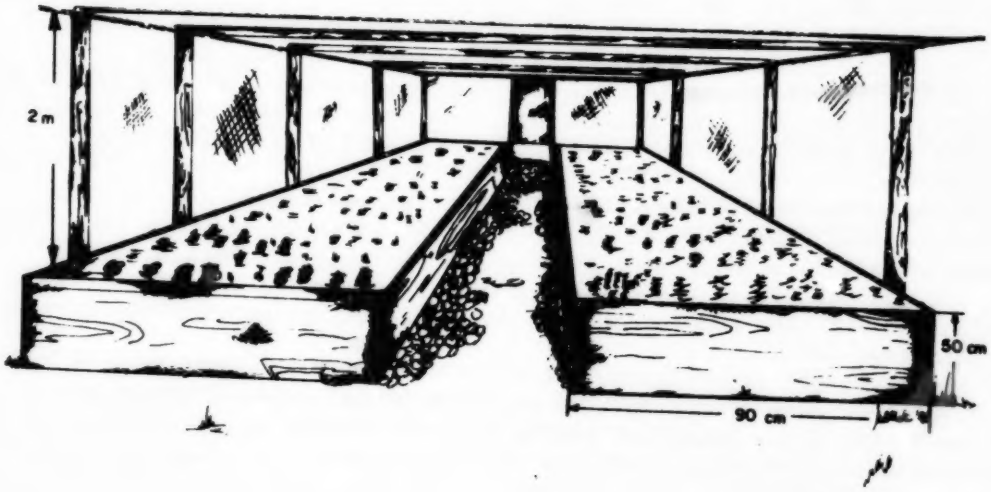

Figure 1 Operational Dunemann beds, illustrating construction and shading. Bed dimensions of 90 cm by 50 cm were used in this study. Length is optional. Elevated wood-lath shades were used to provide 50 percent shade. Side screening to exclude rodents is optional.

In subsequent trials, Dunemann stock survived and grew well after overwinter storage. Height extension was comparable to nursery stock that was one and two years older (Mullin and Hutchison 1981). A reduction in the occurrence of multiple leadering in the Dunemann stock was also noted at time of lifting.

Mullin and Hutchison (1981) suggested that with the Dunemann system small, highly productive nurseries could be established throughout Ontario without "the suitability of local soils and the need for specialized equipment". Thus, Dunemann stock might provide a viable option for nursery, greenhouse or accelerated transplant production.

Extensive trials were conducted at the Midhurst Research Station (44°27'N, 79°46'W), by the now retired Dr. R.E. Mullin, to test and compare the development and field performance of Dunemann stock with stock produced at the nearby Midhurst nursery (44°30'N, 79°45'W).

In this report, the results of these trials are summarized and evaluated to see if the Dunemann system of producing stock is a viable option in Ontario.

MATERIALS AND METHODS

Three trials were conducted comparing germination, 2+0 seedling development and 2+0 outplanting performance of Dunemann and nursery red and white pine and white and Norway spruce (Picea abies (L.) Karst.). Each trial was replicated for four years during which data were collected on germination and seedling morphology.

Description of Dunemann Beds

Eight Dunemann beds were constructed; 4 with cedar and 4 with hemlock lumber (Fig. 1). Each bed measured 90 cm x 610 cm x 50 cm with sides made of 5 cm x 25 cm untreated wooden planks. After ten years of use both wood types showed no signs of excessive deterioration. The raised Dunemann beds were filled with duff collected in 45-year-old local white spruce and red pine plantations. Only the F layer was collected and the litter was neither fumigated nor treated with fungicides.

Four of the beds were filled with white spruce duff and the others with red pine. Each bed was filled to within 5 cm of the top, requiring approximately 2.75 m^3 of duff per bed. This level was maintained by topping up yearly with approximately 0.27 m^3 of duff per bed prior to sowing. Other than topping up, the duff was not changed for the duration of this experiment.

The beds were irrigated to ensure a minimum moisture input of 2.5 cm per week, including rainfall. Fifty percent shading was provided from germination to 2+0 using wood-lath shades elevated 2 m above the seedlings.

Experimental Procedure

Germination. Sowing occurred from May 13 to May 16 in four Dunemann beds for each trial year for four years (1976 - 1979). The seeds untreated with fungicides, were then covered with a light mulch

application of sand and burlap to maintain humidity and prevent erosion. No herbicides were applied. All seeds for both the Dunemann and nursery stock within this trial were collected in Ontario site region 6200 (Hills 1960) but it is unlikely that they were from the same lot. Sowing densities at Midhurst nursery (for 3+0 seedlings) were approximately 375 viable seeds per m^2 for the pines and 590 for spruces while in the Dunemann beds sowing densities were 895 for pines and 1105 for spruces.

In the first year, pine seeds were sown in spruce duff and spruce in pine duff to determine the effects of growing medium on germination and growth. For the remaining three years the seeds of each species were sown in their own duff.

Transplants. A potential use for the Dunemann system is to produce transplant stock. During the 1977 growing season, the height of 25 seedlings was measured weekly from May to September and used to determine seedling height at standard nursery transplant time. Heights for pines on May 1 and for spruces on July 5 were compared to the height requirement for 1+0 and 1.5+0 (mid-summer) transplants, respectively.

During the 1970's two-year-old seedlings (2+0) were generally used as transplant stock. To determine the use of the Dunemann system as a potential source of transplant or shippable material, 50 seedlings of 2+0 Dunemann stock and 50 nursery seedlings (2+0, intended for 3+0) were lifted in late August during each of the four years for morphological comparisons.

Outplanting Performance. In addition 2+0 Dunemann stock and 2+0 nursery stock were outplanted at the end of August in cultivated but otherwise untreated mineral soil. Immediately after planting the seedlings were irrigated. Growth was monitored for 2 years after outplanting.

RESULTS AND DISCUSSION

Germination

Germination in Dunemann beds was nearly complete by June 1, (i.e. 16 to 18 days after sowing). In nursery beds germination usually takes 21 to 30 days. Faster germination enhances survival and subsequent growth. Percent germination in Dunemann beds was generally no different than in the nursery (Table 1).

TABLE 1 Four year averages of percent germination (per viable seeds) of Dunemann stock versus Midhurst nursery stock for four species. Germination counts were made in late July.

Species	Dunemann	Midhurst
Red pine	75	67
White pine	69	68
White spruce	52	51
Norway spruce	74	72

TABLE 2 Degree hardening days (D.H.D.) in Dunemann beds versus Midhurst nursery for four species. Figures shown are for the 1976 growing season and calculated on a 10°C base. Required D.H.D. are currently recommended values for fall lifting for overwinter storage by Mullin and Parker (1976).

Species	Lifting date	Required D.H.D.	Dunemann D.H.D.	Nursery D.H.D.
Red pine	Nov. 15	280	188	312
White pine	Nov. 16	200	202	326
White spruce	Nov. 2	170	118	207
Norway spruce	Nov. 1	170	120	215

Temperature, water and oxygen are the three most important environmental factors influencing the germination process (Kramer and Kozlowski 1979). The Dunemann beds, although in an area where air temperatures averaged 2°C lower than the nursery, had substantially higher soil temperatures which effect degree hardening days (Mullin and Parker 1976). The Dunemann beds had accumulated fewer degree hardening days on the same date and therefore, were considerably warmer during the autumn despite the cooler air temperatures (Table 2). This can provide a somewhat extended growing season, which can increase susceptibility to frost.

Diseases. Forest duff contains fungi and should be tested for harmful pathogens and fumigated if necessary. Damping-off fungus (Fusarium spp.) was observed in small patches among the red pine seedlings around the beginning of August. Ten to fifteen percent of the stock was affected in the first year, but infections were greatly reduced in subsequent years. The impact of pathogen infections can be minimized by use of fungicides and the maintenance of optimal conditions for seedling growth (Armson 1977).

Duff Types. There was no difference in germination between the duff types. Pure spruce duff was recommended by Adolf Dunemann but subsequently various duff types, including hardwood duff, have been used successfully (Aldhous 1962). However, the stage of decomposition of the duff is important as it influences the availability of nutrients (Hutt 1958).

Duff pH. The duff pH will influence nutrient uptake. Therefore, the litter pH should be checked and adjusted if necessary. In this case, pH of the duff varied from 5.2 to 7.0, which is normal for the growth of conifers (Armson and Sadreika 1979). Adjustment of pH of duff may be necessary to optimze seedling growth.

Transplants

Red and white pine 1+2 transplants are currently popular stock types produced in southern Ontario nurseries. Growth progression indicates that 1+0 Dunemann stock will have achieved spring heights of 6.9 cm for red pine (Fig. 2) and 7.3 cm for white pine (Fig. 3). These heights are well above the minimum height of 5 cm required for transplanting.

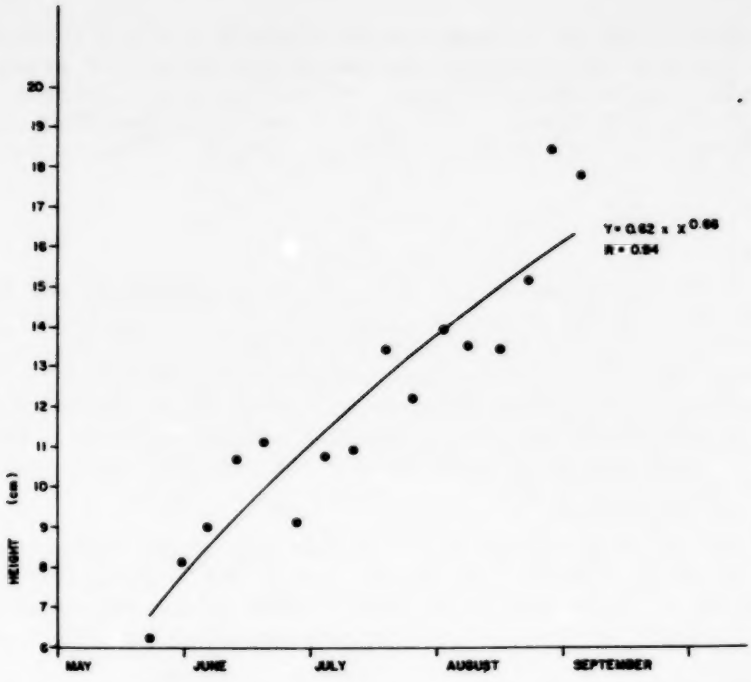

Figure 2 Red pine rising 2+0 growth progression. Regressions of height versus time are based on 16 observations with the least squares fitted equation shown.

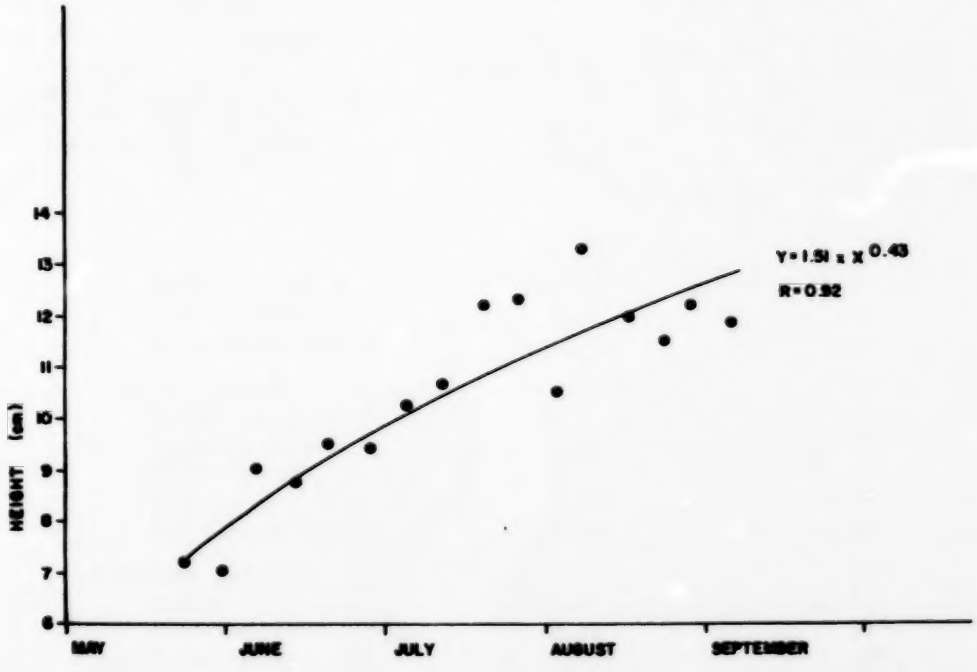

Figure 3 White pine rising 2+0 growth progression. Regressions of height versus time are based on 16 observations with the least squares fitted equation shown.

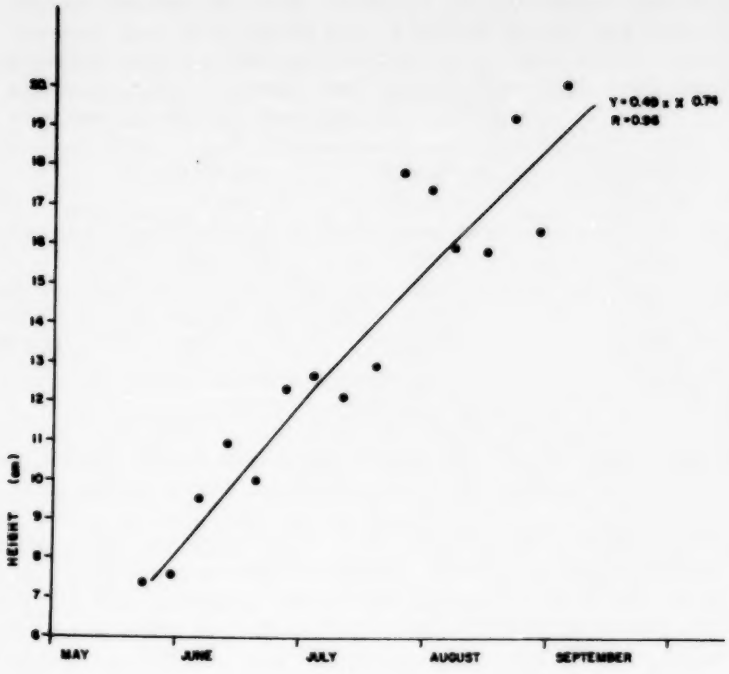

Figure 4 White spruce rising 2+0 growth progression. Regressions of height versus time are based on 16 observations with the least squares fitted equation shown.

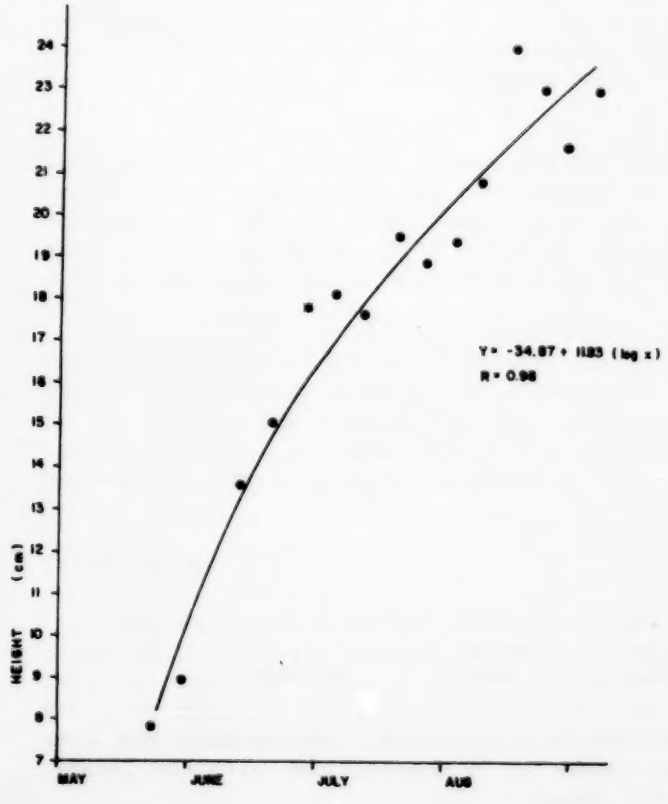

Figure 5 Norway spruce rising 2+0 growth progression. Regressions of height versus time are based on 16 observations with the least squares fitted equation shown.

Spruce 1.5 + 1.5 transplants are popular at many nurseries. The growth curve indicates that Dunemann stock reached a height of 12.6 cm for white spruce (Fig. 4) and 17.1 cm for Norway spruce (Fig. 5) by July 5. Thus, Dunemann white and Norway spruce would make suitable mid-summer transplant material, since a minimum 10 cm height is required.

2+0 Seedlings

The 2+0 seedlings produced with the Dunemann system were compared with those produced in the nursery. Dunemann red pine and Norway spruce seedlings were 62% and 23% taller than their nursery counterparts respectively. Height growth for Dunemann white pine and white spruce were about equal to those of the nursery. Shoot weights generally reflected the shoot length; although there was some indication that for equivalent shoot lengths, dry weights were slightly lower in the Dunemann stock.

Root weights were 42% greater in the nursery stock for red and white pine and 23% greater for Norway spruce than in the Dunemann stock (Table 3). These greater root weights were also reflected in the smaller shoot-root ratios of the nursery stock.

TABLE 3 Morphological parameters for 2+0 Dunemann and 2+0 nursery stock for four species. The figures for all species are the average of 4 years replications, except for the red pine which is the average of 3 years.

Parameter	2+0 Dunemann	2+0 Nursery
Red pine		
Height (cm)	12.7	7.8
Diameter (cm)	0.26	0.27
Shoot Weight (g)	1.55	1.32
Root Weight (g)	0.19	0.27
Shoot/Root Ratio	8.16	4.89
White pine		
Height (cm)	9.4	10.2
Diameter (cm)	0.25	0.26
Shoot Weight (g)	0.89	1.15
Root Weight (g)	0.24	0.34
Shoot/Root Ratio	3.71	3.38
White spruce		
Height (cm)	19.7	19.4
Diameter (cm)	0.29	0.28
Shoot Weight (g)	1.22	1.27
Root Weight (g)	0.25	0.26
Shoot/Root Ratio	4.88	4.88
Norway spruce		
Height (cm)	22.9	18.5
Diameter (cm)	0.29	0.27
Shoot Weight (g)	1.27	1.15
Root Weight (g)	0.30	0.37
Shoot/Root Ratio	4.23	3.11

Growth progression based on dry weight of rising 2+0 Dunemann stock are given in Appendix 1 (Figs. 10 to 13). These curves can be used for comparison with conventional nursery stock.

Density Effects

The sowing densities were higher in the Dunemann beds than in the nursery beds, resulting in seedlings with less dry weight and higher shoot-root ratios. Nursery seedlings grown at lower seedbed densities perform better after outplanting (Mullin and Bowdery 1978). In addition, reduced seedbed density tends to enhance seedling uniformity and reduce cull percentages (McClain 1977). Lowering densities in the Dunemann beds probably would produce more robust seedlings, enhance uniformity and survival after outplanting survival without a great loss of production efficiency.

Root Development

Soil aeration is essential to good root growth (Kramer and Kozlowski 1979, Ledig 1983) but high nutrient availability stimulates more shoot growth in relation to root growth (Ledig 1983).

Lower root weights seem to be characteristic of Dunemann stock, which has a more fibrous root system (Figs. 6 to 9) with a greater number

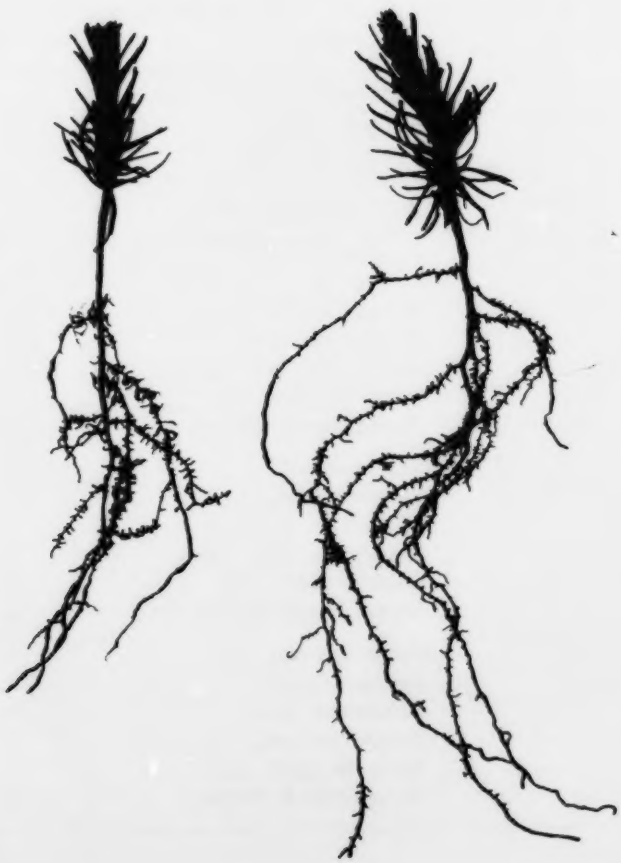

Figure 6 Comparison of nursery (left and Dunemann (right rising 2+0 red pine on May 30, 1979. The silhouette shows the relative balance between top and root and the comparative structure of the root system.

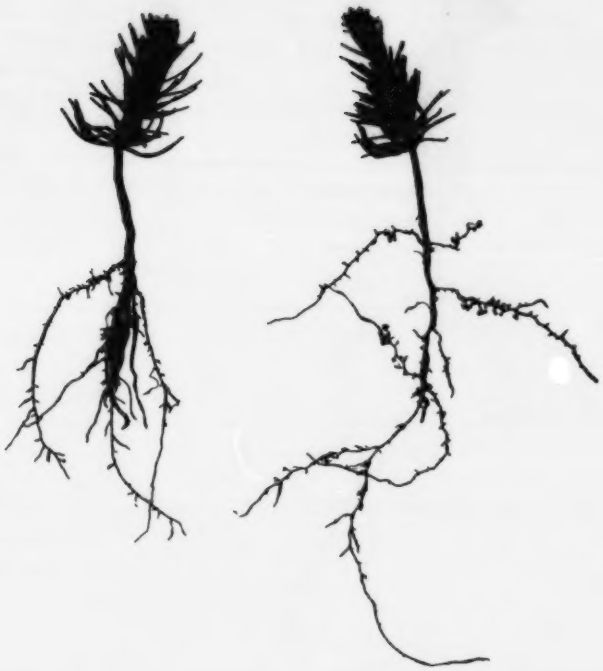

Figure 7 Comparison of nursery (left) and Dunemann (right) rising 2+0 white pine on May 30, 1979. The silhouette shows a marked difference in root structure.

Figure 8 Comparison of nursery (left) and Dunneman (right) rising 2+0 white spruce on May 30, 1979. The silhouette shows a marked difference in root structure and robustness of shoot.

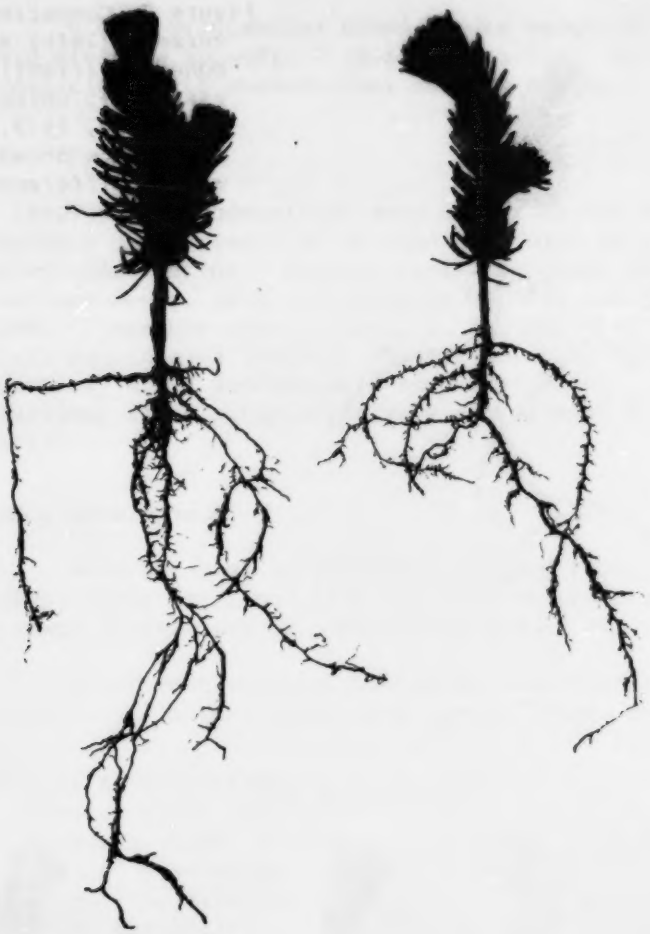

Figure 9 Comparison of nursery (left) and Dunemann (right) rising 2+0 Norway spruce on May 30, 1979. The silhouette shows a larger proportion of fine roots on the Dunemann stock.

of fine roots than nursery stock. This is in agreement with observations by Hutt (1958). The Dunemann growing medium is well aerated, has ample moisture and inherently high nutrient availability, which are probable reasons why Dunemann seedlings develop a finer root system.

Cull

The Dunemann system used 2 to 3.5 viable seeds sown to produce one shippable tree. At southern Ontario nurseries the "rule of thumb" is 4 to 8 seeds sown per tree. With a higher proportion of the seed sown achieving shippable size, Dunemann beds make more efficient use of seed and available growing space.

The frequency of double and multiple leaders is quite low in Dunemann stock (Table 4). Multiple leadering has been the subject of many recent investigations at Ontario nurseries (Gross 1983, Webb and Reese 1984, Hofstra 1984). The Dunemann system may offer further insight into the causes of this problem and how it can be avoided.

Culling due to root damage was 1% or less for all species, reflecting the ease of lifting from a duff growing medium. Similar observations were made by Hutt (1958). Since Dunemann seedlings have

TABLE 4 Percent cull in Dunemann production, classified by form of cull, for three species. The values listed are the average percentages of the total 2+0 seedlings lifted during the four replicates. Similar nursery values and data on red pine were not available.

	Midhurst Nursery	Dunemann	Form of cull			
Species	Total cull	Total cull	Single stem	Double stem	Multiple stem	Torn root
White pine	30	12	6	<1	5	<1
White spruce	30	36	21	9	5	1
Norway spruce	25	25	9	7	8	<1

such fine roots, minimal lifting damage is critical to their future performance.

Weeding

One of the major advantages of the Dunemann system is a significant reduction in weeds, thus eliminating the use of herbicides (Grant 1952). In addition to a direct cost savings in herbicide applications, growth reductions due to herbicides are not a factor in Dunemann production (Hull et al. 1967). Our records of weeding time indicate that it takes from 2.2 to 2.6 minutes per m^2 for Dunemann beds. Heavy weeding in nursery beds at Midhurst nursery requires 4.2 minutes per m^2 and light weeding 1.8 minutes per m^2 (Maurer 1984). Weeding operations in Dunemann beds required the same amount of time as weeding an average crop at the nursery. However, with a greater number of seedlings per m^2 shipped, the cost per Dunemann seedling was lower.

2+0 Outplanting Performance

Both nursery grown and Dunemann grown red pine performed poorly after outplanting but the Dunemann stock had 10% less survival (Table 5). Diameter growth and dry weight were greater in Dunemann stock but final heights were equal. The late August lifting date is not recommended.

Seedling development of Dunemann white pine was not significantly different than that of nursery stock but survival was 12% better. For both white spruce and Norway spruce, Dunemann seedlings were comparable in development to nursery stock.

The lower root weight of Dunemann stock does not impair its outplanting performance, probably because of more fine roots. Both Dunemann and nursery seedlings developed more balanced shoot-root characteristics as a result of transplanting.

The option of using Dunemann beds for growing 1-year-old deep rooting species such as walnut and butternut warrants exploring. Recently four Dunemann beds were used for growing these two species for

TABLE 5 Dunemann (D) and nursery (N) 2+0 stock outplanting performance for four species. Results shown are initial, final and the tota change for 2 year growth increment (net growth) for each morphological parameter. White pine and white and Norway spruce data represent the average of 4 years of replications, while red pine data represents a one year experiment.

Parameter	2+0 Initial		2+2 Final		Net growth	
	D	N	D	N	D	N
Red pine						
Survival (%)	71	55	40	50		
Height (cm)	16.0	7.8	32.1	31.2	16.1	23.4
Diameter (cm)	0.29	0.26	1.01	0.62	0.72	0.36
Shoot Weight (g)	1.83	1.25	31.20	9.98	29.37	8.73
Root Weight (g)	0.20	0.24	5.60	1.82	5.40	1.58
Shoot/Root Ratio	9.15	5.21	5.57	5.48		
White pine						
Survival (%)	95	83	95	83		
Height (cm)	9.4	10.2	24.7	26.3	15.3	16.1
Diameter (cm)	0.25	0.26	0.76	0.83	0.51	0.57
Shoot Weight (g)	0.89	1.15	13.68	16.94	12.79	15.79
Root Weight (g)	0.24	0.34	4.99	5.64	4.75	5.30
Shoot/Root Ratio	3.71	3.38	2.74	3.00		
White spruce						
Survival (%)	99	99	99	99		
Height (cm)	19.7	19.4	37.7	36.6	18.0	17.2
Diameter (cm)	0.29	0.28	0.91	0.97	0.62	0.69
Shoot Weight (g)	1.22	1.27	21.79	23.47	20.57	22.20
Root Weight (g)	0.25	0.26	7.53	8.20	7.28	7.94
Shoot/Root Ratio	4.88	4.88	2.89	2.86		
Norway spruce						
Survival (%)	99	99	99	99		
Height (cm)	22.9	18.5	45.7	43.9	22.8	25.4
Diameter (cm)	0.29	0.27	0.94	0.95	0.65	0.68
Shoot Weight (g)	1.27	1.16	28.15	27.66	26.88	26.50
Root Weight (g)	0.30	0.37	9.87	10.05	9.57	9.68
Shoot/Root Ratio	4.23	3.14	2.85	2.75		

one year. The nuts were sown in the fall, germinated well the following spring and by the end of the growing season were about 1 m tall. In late fall the seedlings were easily lifted for overwinter storage without damage to the large tap roots.

CONCLUSION

The Dunemann system relies on its own productive growing medium and therefore, could be established at any location with a nearby source of needle litter. This would be particularly important in remote northern locations. The growing medium of white spruce and red pine litter satisfies all the seedling's mineral nutrient requirements for at least 4 years. Black spruce and jack pine litter would probably produce similar

results. Supplies of duff appear to be large. Dunemann beds should be shaded and irrigated.

Higher sowing densities can be used in Dunemann beds than nursery beds, and fewer seeds are required to produce a shippable quality seedling. This results in efficient use of growing space and lower production costs with no reduction of stock quality in comparison with nursery seedlings of similar age. Sowing densities in this study were probably too high. Better densities are likely 900 viable seeds per m^2 for spruce and 700 seeds per m^2 for pine in order to produce more robust seedlings, increase uniformity and probably improve outplanting performance. Dunemann white pine and white and Norway spruce are suitable for transplant or 2+0 seedling production. Dunemann stock produced height gro th comparable to nursery seedlings.

The Dunemann system has potential as an alternative to nursery beds or greenhouse production. The cost per shippable seedling is less than production in nursery beds. Dunemann production appears particularly well suited to situations which are limited in space, soil quality or access to heavy equipment. No heavy equipment is needed. This would be especially attractive to independent growers as the initial capital investment is small. It could be effectively used as a temporary production facility for transplant stock or 2+0 planting stock.

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APPENDIX 1

Dry Weight Growth Progressions

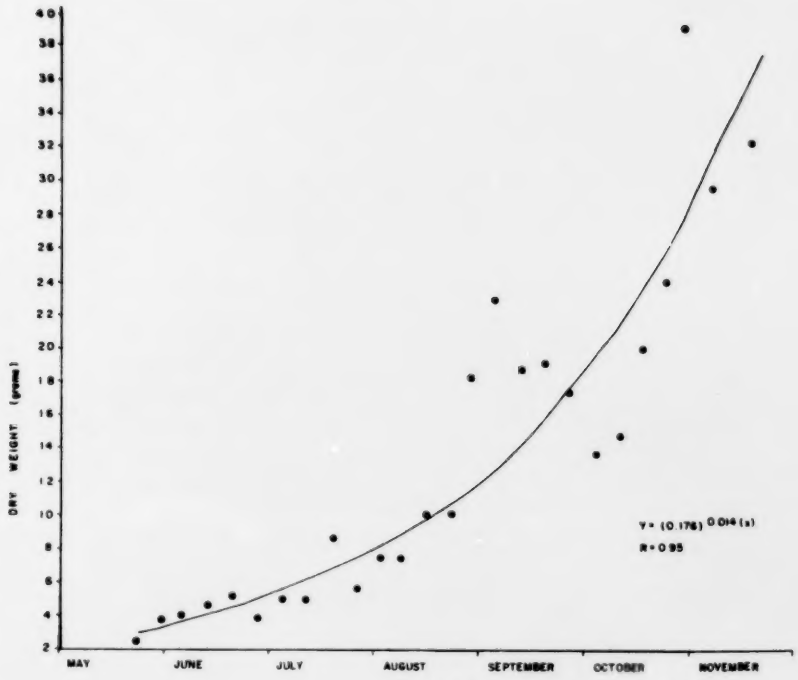

Figure 10 Dry weight progression of rising 2+0 Dunemann red pine for the 1977 growing season.

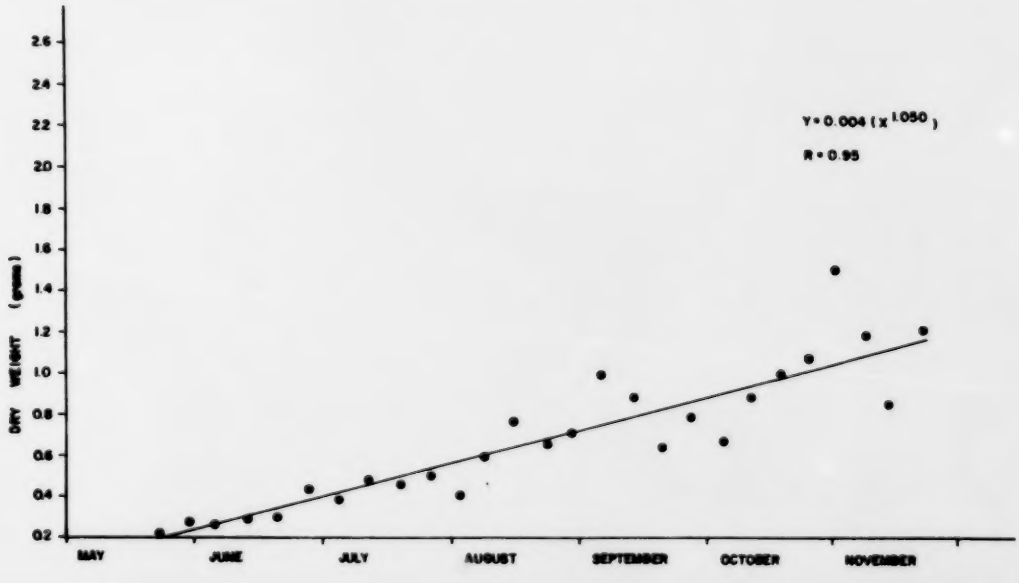

Figure 11 Dry weight progression of rising 2+0 Dunemann white pine for the 1977 growing season.

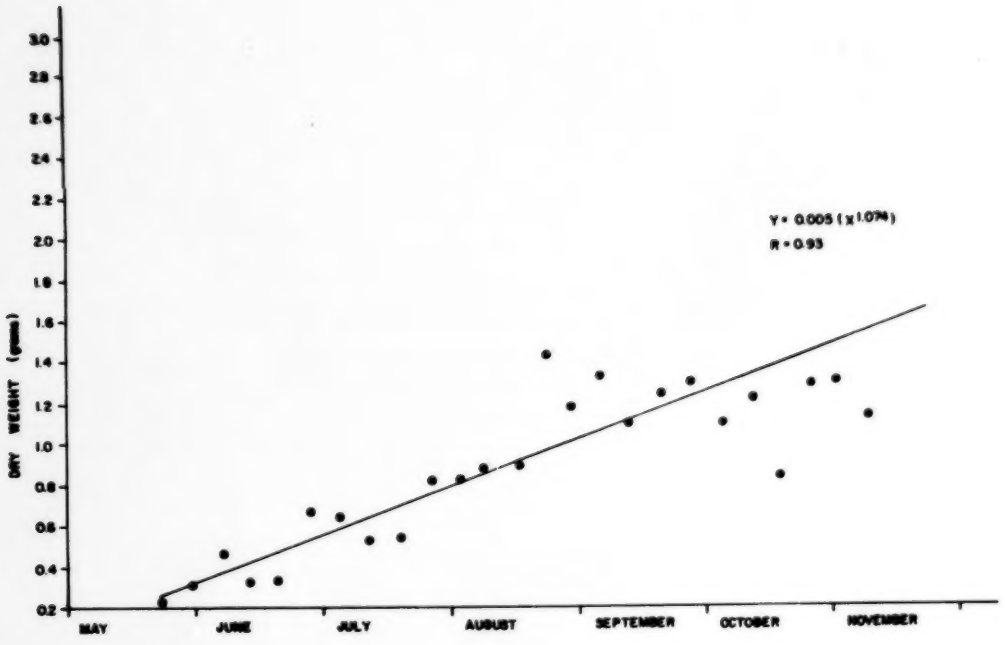

Figure 12 Dry weight progression of rising 2+0 Dunemann white spruce for the 1977 growing season.

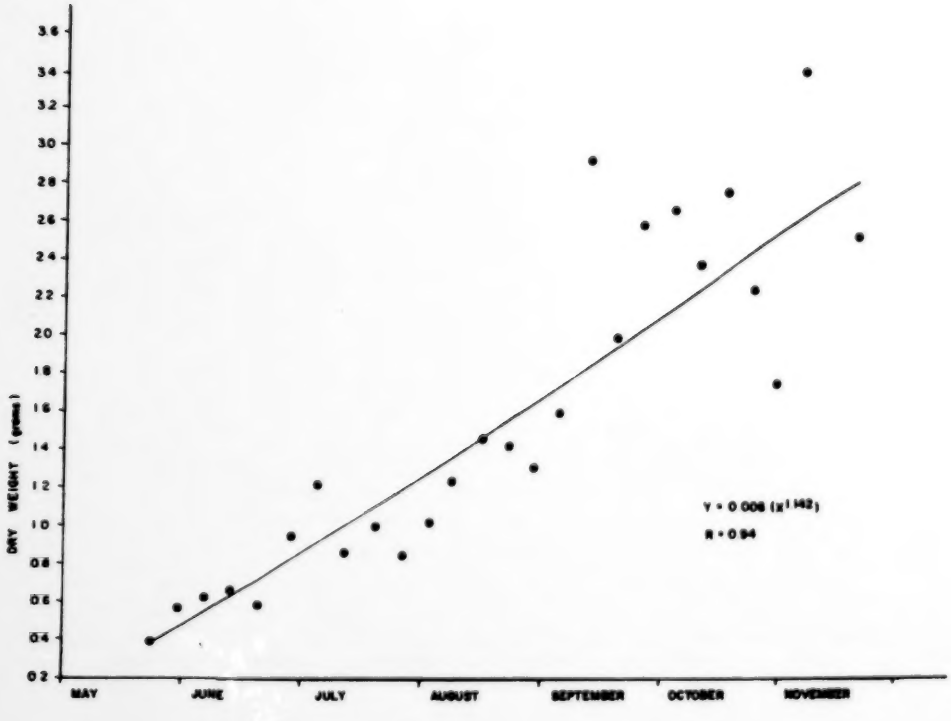

Figure 13 Dry weight progression of rising 2+0 Dunemann Norway spruce for the 1977 growing season.